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**To: Tom Bolen, Northwest Arctic Borough**

**From: John DeGeorge, PE, Nana Pacific, LLC**

**Date: October 11, 2006**

**Re: Kivalina Seawall – Grouting Recommendations**

Following the Kivalina storm which occurred on September 11 and 12, 2006, NANA Pacific (NP) inspected the storm damage to the Kivalina seawall on September 15 and 22, 2006. Subsequent to our visits, we agreed to assist the Northwest Arctic Borough (NWAB) in establishing a remedy to strengthen or stabilize the seawall. We met with representatives of Grancrete Distributors to discuss their proposed product, which is typically applied as a spray, or shotcrete, to create a hardened coating. Despite their commitment to modify their product so it could be applied as a grout, we do not recommend this product, due to its un-tested, modified quality. We believe it is essential that an experienced applicator with a proven grout product be utilized.

We considered two major classes of grout for this project: particulate grouts and chemical grouts. These two grouts are commonly used at low pressures to permeate the soil, also known as permeation grouting. The particulate grout is commonly a Portland cement, water, and bentonite mixture, and the chemical grout is generally a sodium silicate, acrylate, or polyurethane formulation that includes a catalyst to control gel time.

In our memorandum dated September 29, 2006, NP noted that a benefit to using a particulate grout was due to the relative abundance of Portland cement throughout the state. It should be noted that the grain sizes of the various Portland cements are significantly different; for instance, the average grain size of Portland Type I/II cement is 50 microns whereas the average grain size of Portland Type III cement is 20 microns. Due to its smaller grain size, the Portland Type III cement is more commonly used for permeation grout applications. This type of cement (Type III) is about 5% more expensive than Type I/II, but more significantly, may not be as abundant in proximity to Kivalina.

The “groutability ratio” (N) is a common measure used to determine if a soil is ideal for a particulate grout. It is defined as  $N = D_{10}(\text{soil}) / D_{95}(\text{grout})$ , where  $D_{10}$  is the soil grain size that corresponds to 10% of the sample passing (by weight) in a sieve analysis, and  $D_{95}$  is the grout size that corresponds to 95% of the sample passing (by weight) in a sieve analysis. Based on the grain size distribution curves for three representative samples of the seawall fill contents, a particulate grout must consist of Portland Type III cement, or a finer-grained cement such as microfine cement.

The chemical grouts do not contain particulates and therefore have the ability to permeate soils with smaller grain sizes and smaller pore spaces between grains. Due to the way the concertainers were filled using an excavator bucket, it is not likely that any fine-grained sands would have concentrated in any zones which would impede the flow of particulate grout. However, it is possible that sections of the seawall, especially those sections that have recently been bombarded by waves, may have achieved a higher density making these sections less permeable for a particulate grout. An experienced applicator should be able to detect a significant increase or decrease in density of the fill material and make adjustments to the mixture and application pressure.

Due to the intent of the grouting procedure to permeate the fill, and not displace the fill, the grouting procedure will only withstand a pressure equal to the overburden pressure before hydrofracturing occurs. This pressure is low compared to other grouting techniques such as compaction grouting. Application pressures at the nozzle should not exceed about 0.75 psi for each foot of overburden. Since a particulate grout does not possess any expansive qualities, it is reliant on its application pressure to intrude the pore spaces within the sand and gravel (fill) matrix. A chemical grout would utilize both the application pressure and its expansive qualities to permeate the fill.

The gel time for a chemical grout is within minutes, compared to the gel time for a particulate grout which is within hours. A faster gel time will make it easier for the applicator to conduct test sections and inspect the effectiveness of the application method. Chemical grouts do not absorb moisture as much as cement grouts and therefore tend to have higher compressive strength. Chemical grouts also act as a water-repellent by having a low absorptive capacity.

The chemical grout recommended by NP is a polyurethane-based resin. The formulation has a low viscosity of 40 centipoise (similar to linseed oil) making it ideal for penetrating sands of various grain sizes. It expands up to 29 times its original volume (in the laboratory), but for estimating, a conservative lower expansion ratio is used. Depending on the expansion ratio achieved in the field, the material order has the potential of being significantly reduced.

## **Conclusions and Recommendations**

Either a particulate grout or a chemical grout may be applied to the Kivalina seawall to strengthen or stabilize the wall. A thorough penetration of grout within the most critical baskets should mitigate the liquefaction potential of the sand and gravel contents. Due to specific manufacturing and assembly deficiencies identified in the HESCO Concertainers, a decrease in excess porewater pressures caused by liquefaction should enable the baskets to last longer without losing their integrity.

In conclusion, NANA Pacific recommends stabilizing the seawall by using a chemical grout over a particulate grout due to the following reasons: 1) chemical grout has a better permeation capability in finer grained sands and densified sands, 2) chemical grout produces a material with higher compressive strength upon cure, 3) Portland Type III Cement may not be readily available near Kivalina, requiring additional shipping costs, 4) chemical grout utilizes its expansive qualities to permeate within a soil, in addition to the permeation gained by its application pressure, 5) chemical grout solidifies within minutes, enabling the applicator to quickly confirm field results, 6) a potentially high expansion ratio could reduce material volume and likewise cost, and 7) preliminary cost estimates indicate that chemical grouting can be achieved for as

much as \$300,000 less than particulate grouting. One apparent reason for this offset can be attributed to the potable mixing water, water tank, extra pump, and mixing container required for particulate grouting. Other reasons may be due to the number and sizes of equipment required for the project, as well as the number of man-hours.

The estimated project costs were calculated by estimating the amount of material necessary to grout the entire length of wall pertaining to the critical baskets to be grouted. These baskets were identified as the second basket of the bottom tier and the first baskets of the second and third tiers. Significant savings can be achieved by reducing or eliminating some sections of the wall or else optimizing materials in accordance with shipping weight restrictions.

The proposed grouting operation should not be conducted once freeze-up has occurred, as potential ice crystals within the sand matrix can cause an un-even distribution of grout. We recommend that a test section be conducted to optimize and confirm the effect of the grout application process. In addition, we recommend initiating the project with a partial order of materials, and then completing the order once a production rate is established.

In closing, NANA Pacific reiterates the importance of using an experienced grout applicator for this project, regardless of the grout type chosen. The equipment and technique employed by the grout applicator will be critical in optimizing the volume of grout and achieving full permeation of the void spaces in the most critical areas.